10/554102
JC12 Rec'd PCT/PTO 21 OCT 2005

Attorney Docket No. 010405.56864US
Marked up Substitute Specification

METHOD AND RECEIVER FOR THE SIMULTANEOUS DETECTION AND ANALYSIS OF AT LEAST TWO ELECTROMAGNETIC SIGNALS

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] This application claims the priority of German patent document 103 18 580.1, filed April 24, 2003 (PCT International Application No. PCT/DE2004/000853, filed April 22, 2004), the disclosure of which is expressly incorporated by reference herein.

[0002] The present invention relates to a method and ~~a receiver~~ apparatus for [[the]] simultaneous detection and analysis of at least two electromagnetic signals, such as may be ~~. Such a method or such a receiver can particularly be~~ used in a spacecraft, in particular.

[0003] ~~Spacecraft~~ The term spacecraft in the sense of the invention [[are]] includes all artificial bodies designed for use in outer space, ~~particularly also~~ including satellites, space probes, space shuttles, space stations or rockets. However, in principle, the method and apparatus ~~the receiver~~ can also be used for terrestrial applications. ~~Receivers~~ The term receivers in the sense of the invention [[are]] includes all devices which are designed ~~for receiving and processing~~ to receive and process electromagnetic radiation, for example, for the purpose of the data exchange between spacecraft, or between the spacecraft and earth stations, or

between other objects, or also for the purpose of the detection, locating, measuring and/or observation of objects emitting electromagnetic radiation. Signals in the sense of the invention are represented by any type of electromagnetic radiation which can be detected by a receiver according to the invention, [[;]] thus[[,]] including radiation actively emitted by an object as well as passively scattered or reflected by an object.

[0004] ~~From the state of the art,~~ German patent document DE 198 46 690 A1 discloses an optical receiver system ~~is known from German Patent Document DE 198 46 690 A1,~~ which is constructed in the form of a combined earth-star sensor, and ~~. The latter~~ is used for observing the earth and the stars. From the obtained information, a three-axis attitude and position determination of satellites is permitted.

[0005] An optical receiver system for optical intersatellite connections is ~~known from~~ disclosed and described in detail in German Patent Document DE 198 47 480 A1. ~~The corresponding optical receiver is described in sufficient detail in German Patent Document DE 198 47 480 A1.~~ Such intersatellite connections are used for exchanging data between individual satellites, but can also be ~~utilized for determining~~ used to determine the attitude of a satellite, as in the case of German Patent Document DE 198 47 480 A1.

[0006] However, a problem arises in the case of arrangements from the state of the art when ~~simultaneously~~ two or more electromagnetic signals that are to be

detected simultaneously ~~which~~ are mutually superimposed on a common detector. Here, it ~~has to~~ must be possible [[to]] nevertheless to separate ~~carry out a sufficient separation of~~ the individual electromagnetic signals sufficiently to permit ~~which permits~~ a clear identification of the individual electromagnetic signals. ~~It is another~~ Another problem is that a distortion of detected radiation images often occurs in the area outside the optical axis of the receiver. This is ~~particularly relevant~~ especially important when one of the electromagnetic signals ~~has to~~ must be determined with a particularly high precision. The ~~arrangements from the~~ state of the art ~~offer~~ offers no satisfactory solution for this purpose.

[0007] It is therefore an object of the invention to provide a method and a receiver apparatus for [[the]] simultaneous detection and analysis of at least two electromagnetic signals, which eliminates the disadvantages of the state of the art.

~~This object is achieved by means of the characteristics of Claims 1 and 8.~~

~~A first object of the present invention relates to a method for the simultaneous detection and analysis of at least two electromagnetic signals by a joint detector, the detection and analysis of at least one radiation image signal taking place.~~

[0008]

[0009] ~~According~~ This and other objects and advantages are achieved by the method according to the invention, ~~the method~~ which comprises the following steps:

- Division of an input radiation image into at least two partial images

- Projection of the partial images on a radiation detector; and [[,]]

- ~~an imagining of~~ imaging the partial images on the radiation detector ~~taking place~~ in such a manner that radiation intensities of the partial images are projected from the image center of the input radiation image to the edge of the radiation image on the detector.

[0010] In this case, a planar expanded electromagnetic radiation signal is considered to be the radiation image signal, which radiation signal appears as an image and not only as in a largely punctiform shape when it is projected on the detector.

[0011] The advantage of the method according to the invention ~~consists of~~ lies in the fact that the radiation image, which as an expanded radiation signal is less susceptible to distortions, is displaced into edge areas, ~~whereby~~ so that the area around the optical axis can be utilized for the - simultaneous - detection of less expanded signals, ~~which can now, however, take place~~ in a more precise manner. This applies particularly if, in addition to the radiation image, the exact position of another signal of a smaller expansion is to be detected. In addition, [[a]] mutual ~~interfering influence~~ interference of the signals that are to be simultaneously detected can be avoided (or at least ~~reduced~~ diminished) as a result of the displacement of the radiation intensities of the partial images into the edge area.

This is particularly applicable when the radiation intensities of the radiation image are approximately equally ~~high as~~ to or even ~~higher~~ greater than the radiation intensity of the at least one other signal. The detector surface can also be used more effectively by the displacement of the radiation intensities from the image center of the radiation image into the edge area.

[0012] The projection of the radiation intensities of the partial images from the image center of the input radiation image to the edge of the radiation image can ~~particularly~~ take place in particular if ~~in that~~ the partial images of the input radiation image are reflected. However, as an alternative, it can also be provided that the partial images of the input radiation image are displaced in the direction of the image edge.

[0013] The division of the input radiation image can take place into any suitable number and shape of partial images which permit the displacement of the radiation intensities from the image center of the input radiation image to the edge of the radiation image. Thus, in the case of a square input radiation image, ~~in can particularly be provided that a division of~~ the input radiation image ~~takes place~~ can be divided into four partial images, with ~~and an~~ imaging of the partial images ~~takes place~~ such that radiation intensities are projected from the image center of the input radiation image in the direction of a corner of the radiation image on the detector. However, ~~basically, for example,~~ a division into only two partial images or into a larger number of partial images [[may]] is also ~~take place~~ possible.

[0014] In principle, the method according to the invention can be used for all suitable types of electromagnetic signals, one of ~~these signals being present as~~ which is a radiation image signal. Thus, for example, a data communication signal can be detected as one of the electromagnetic signals, for example, in addition to a radiation image signal. A usage for this purpose can take place, for example, within the scope of data connections between objects, such as particularly spacecraft or the like. For this purpose, reference is also made to the statements in the introduction to the specification.

[0015] In a special application of the present method, it may be provided that radiation images of reference objects, particularly celestial bodies, are detected as radiation image signals. This can be provided particularly when an identification or position determination of certain reference objects, such as particularly celestial bodies, is to take place. ~~By means of the~~ The information thus obtained ~~information~~ can be used, for example, [[a]] to determine position ~~information~~ and/or attitude information ~~can then be obtained~~ relative to the corresponding reference object. However, in addition to [[this]] the detection of one or more reference objects, other electromagnetic signals, such as those of largely punctiform signal sources can also be detected. The latter ~~, which~~ may be used, for example, ~~for obtaining~~ to obtain additional position information and/or attitude information, and [[but]] also, for example, for the data communication.

[0016] In a [[A]] special embodiment of the above-mentioned method, which is used particularly for spacecraft, ~~provides that simultaneously~~ radiation images of the earth and the stars are detected simultaneously and the image of the earth is divided into partial images. As a result, it ~~can be achieved that~~ is possible to detect the, as a rule, largely punctiform electromagnetic signals [[,]] (which usually have a lower intensity) ~~, can be detected~~ in the optical axis of the detector [[- thus]] and therefore largely without any distortion. This arrangement [[-, which]] permits a precise position determination of the stars. In contrast, the more expanded (and, as a rule, higher-intensity) radiation image of the earth is displaced to the edge of the detector, [[thus]] into an area outside the optical axis of the detector. Thus, a detection of the earth and the stars is permitted with a greater precision than in the state of the art while the mutually influencing of the respective signals is simultaneously reduced.

[0017] Another ~~object~~ feature of the present invention is the provision of a receiver having a device for [[the]] simultaneous detection and analysis of at least two electromagnetic signals by a joint detector, ~~the device being designed for the detection and analysis of~~ at least one of which is a radiation image signal. According to the invention, at least one radiation image splitter is [[now]] provided for dividing the input radiation image into at least two partial images ~~as well as for~~ and projecting them ~~the partial images~~ onto a radiation detector. The latter [[, which]] is designed such that ~~an imaging of~~ the partial images are formed on [[onto]] the radiation detector ~~takes place in such a manner that~~ with their

radiation intensities ~~of the partial images are~~ projected from the image center of the input radiation image to the edge of the radiation image on the detector. Analogously, the advantages which were illustrated for the method according to the invention are obtained for the receiver according to the invention.

[0018] In particular, the radiation image splitter can be designed such that the partial images of the input radiation image are reflected. However, the radiation image splitter may also be designed in such a manner that the partial images of the input radiation image are displaced in the direction of the image edge.

[0019] [[For]] In the case of a square input radiation image, the radiation image splitter can particularly be designed such that ~~the division of~~ the input radiation image ~~takes place~~ is divided into four partial images, whose ~~and an imaging of the partial images takes place such that the~~ radiation intensities are projected from the image center of the input radiation image in the direction of a corner of the radiation image on the detector.

[0020] ~~In particular, the~~ The receiver can also be constructed as part of a data communication device. For this purpose, reference is made to the statements concerning the method according to the invention.

[0021] The receiver can also be designed as a sensor for the detection of radiation images of reference objects, ~~particularly of~~ such as celestial bodies. In this respect, reference is also made to the statements concerning the method according to the

invention. A combination with another detection method of signals, for example, for the data communication, can also be provided in the case of the receiver according to the invention. The receiver may be designed, for example, as a combined earth-star sensor.

[0022] In principle, the receiver can be designed for any suitable wavelength or any suitable wavelength range. In particular, it can be provided that the receiver is designed as an optical receiver.

[0023] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

~~A special embodiment of the present invention will be illustrated in the following by means of Figures 1 to 7 on the example of an optical receiver.~~

[0024] Figure 1 is a schematic representation of an optical receiver according to the invention;

[0025] Figure 2 is a schematic representation of the division of an input radiation image into partial images;

[0026] Figure 3 is a schematic representation of the projection of displaced partial images on the detector;

[0027] Figure 4 is a schematic representation of the projection of reflected partial images on the detector;

[0028] Figure 5 is a representation ~~analogous~~ corresponding to Figures 1 and 2 without a radiation image splitter for a combined earth-star sensor;

[0029] Figure 6 is a representation ~~analogous~~ corresponding to Figures 1 and 4 with a prism arrangement as a radiation image splitter for a combined earth-star sensor; and

[0030] Figure 7 is a representation ~~analogous~~ corresponding to Figures 1 and 4 with a mirror arrangement as the radiation image splitter for a combined earth-star sensor.

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] Figure 1 is a purely schematic view of a special embodiment of an optical receiver 1 according to the ~~present~~ invention, which ~~. This receiver 1~~ has a first expanded aperture 2 for ~~the detection of~~ detecting an expanded optical radiation image signal, and a second aperture 3 for ~~the detection of~~ detecting less expanded optical signals. In the example according to Figure 1, the two apertures 2, 3 are arranged perpendicular to one another. However, ~~another suitable~~ other arrangement of the apertures 2, 3 [[is]] may also ~~conceivable~~ be suitable.

[0032] The radiation image signal entering through the aperture 2 is projected on an optical detector 6. The optical signal entering through the aperture 3 is projected on the detector 6, for example, by way of a mirror 5. (For the ~~implementation or optimization~~ implementing or optimizing of the projection, a correspondingly constructed imaging lens system 10 can ~~additionally~~ be provided.) The optical radiation image signal and the additional optical signal are then mutually superimposed on the detector 6. The mirror 5 ~~can also be constructed as a~~ may be semitransparent, in which case, ~~mirror. As a result, a superposition of~~ the two optical signals can already ~~take place by means of the semitransparent mirror~~ be superimposed.

[0033] Figure 2 shows the ~~situation of the~~ superposition of the two optical signals, as it would occur without any further influence on the radiation image signal. It is assumed that the input radiation image signal comprises a square optical ~~input radiation~~ image 9, which contains ~~is the radiation image signal, the input radiation image 9 containing~~ the optical image of a reference object 7. Furthermore, another (largely punctiform) signal 8 is assumed which was detected by the aperture 3. The additional, largely punctiform optical signal 8 would then normally be superimposed on the input radiation image signal 9, as [[. As]] illustrated in Figure 2. Signal, ~~signal~~ 8 is imaged in the image center, and thus in the optical axis of the detector 6, in order to avoid distortions, if possible. However, in this case, the superpositioning of ~~especially~~ the optical image of the reference

object 7 ~~is superimposed~~ on the optical signal 8 ~~, which~~ makes it difficult to separate ~~a separation of~~ the optical signal 8 from that of the reference object 7 ~~difficult~~.

[0034] ~~In order to~~ To avoid this problem, the input radiation image 9 is divided into two partial images TB1 and TB2, before a superposition takes place with the additional optical signal. (The two partial images are already illustrated in Figure 2.) For this purpose, a radiation image splitter 4 is provided in the optical receiver, as ~~purely~~ shown schematically ~~shown~~ in Figure 1. However, a division can also take place into more than [[only]] two partial images or into partial images having a different shape.

[0035] The radiation image splitter can [[now]] be designed such that ~~either~~ the partial images TB1 and TB2 (the image parts of the reference object image 7) are displaced toward the image edge, that is with their ~~in such a manner that the~~ radiation intensities [[are]] displaced from the [[image]] center of the [[input]] radiation image 9 ~~, thus the image parts of the reference object image 7,~~ to the image edge, as [[. This]] is illustrated in Figure 3. Only the optical signal 8 will now remain in the image center, and can now be detected without being influenced by the radiation image of the reference object 7. Also, the surface of the detector 6 is now utilized more effectively because ~~also the~~ its edge areas are also utilized for a signal detection.

[0036] Figure 4 illustrates an alternative to Figure 3, in which no displacement but a suitable reflection of the partial images TB1, TB2 takes place. As a result of

this suitable reflection, the radiation intensities corresponding to the image parts of the reference object image 7 are again imaged away from the [[image]] center of the [[input]] radiation image 9, ~~this the image parts of the reference object image 7, onto~~ in the area of the image edge. As a result, as in the case of Figure 3, the optical signal 8 can now be detected without being influenced by the radiation image of the reference object 7.

[0037] The additional optical signal 8 may represent, for example, ~~represent~~ an optical data communication signal, but also a largely punctiform reference signal of an artificial or natural radiation source, such as a star. Thus, either information within the scope of a data transmission can be obtained from the optical signal 8, or corresponding position or attitude information can be obtained concerning a position determination of the origin of the optical signal 8.

[0038] Figure 5 [[now]] illustrates a special embodiment of the optical receiver 1 of the above-mentioned example, in ~~within the scope of~~ a combined earth-star sensor, which ~~. The latter~~ also has two apertures 2, 3. An ~~as well as an~~ arrangement 5, such as a semitransparent mirror, is provided for ~~the superposition~~ superpositioning [[of]] two radiation image signals 8, 9 [[- here,]] (the input radiation image 9 of the earth 7 and the radiation image signal 8 of selected stars 12). [[-.]] The two superimposed radiation image signals 8, 9 are then imaged on a detector 6 by a suitable lens system 10. In the case according to Figure 5, the two radiation image signals 8, 9 would therefore be imposed on one another such that

the optical signal 8 of the stars 12 would be superimposed on the optical input radiation image 9 of the reference object earth 7 directly in the optical axis 11 of the detector 6, as shown in Figure 5 on the right. As a result, the signal 8 of the stars 12 could hardly be separated from the radiation image signal 9 of the earth 7, because of the higher radiation intensity of the radiation image signal of the earth 7.

[0039] ~~In order to~~ To avoid this problem, four partial images TB1 to TB4 of the radiation image signal 9 of the earth 7 are generated, which[[,]] are displaced to the edge of the radiation image 9, by ~~means of an~~ optical imaging[[,]] (for example, by means of prism arrangements or mirror arrangements), ~~are displaced to the image edge of the input radiation image 9. This is~~ as illustrated in Figures 6 and 7.

[0040] Figure 6 shows an example in which a prism arrangement is used. However, ~~during the selection of the~~ in selecting a suitable prism arrangement, ~~attention~~ it should be ~~paid to the fact~~ taken into account that an achromatic imaging of the radiation images takes place if the radiation images are not monochromatic radiation image signals. This problem can ~~basically~~ be avoided if, instead of a prism arrangement, a reflective arrangement, with ~~by means of~~ appropriately arranged and appropriately shaped mirrors, is used, as illustrated in the manner of an example in Figure 7.

[0041] In the example according to Figure 6, a radiation image splitter 4 with a suitable prism arrangement is connected in front of the semitransparent mirror.

The ~~, which~~ prism arrangement causes a quadruplication of the input radiation image 9 while simultaneously displacing the individual radiation images with respect to one another in the direction of the corners of the original input radiation image 9. In this case, only the displaced partial images TB1 to TB4 are detected in the corners on the detector 6 illustrated on the right in Figure 6. In contrast, only the optical signal 8 of the stars 12 is imaged in the optical axis 11 of the detector. On the detector 6, the stars 12 have a much smaller expansion and therefore appear largely in a punctiform shape. By means of the arrangement according to Figure 6, it is ensured that the position of the stars 12 can be detected largely without distortions and without ~~interfering impairments by~~ interference from the radiation image of the earth 7. As ~~and, as~~ a result, more precise position and attitude information for the earth-star sensor can be obtained with respect to the earth 7 and the stars 12.

[0042] The arrangement according to Figure 7 corresponds largely to the arrangement according to Figure 6. (For a simplification and better clarity of the representation, the apertures 2, 3, ~~are not shown in Figure 7. These apertures~~ which would also have to be provided here corresponding to Figure 6 are not shown in Figure 7.) In the example according to Figure 7, the prism arrangement 4 was replaced by a mirror arrangement 13 which consists of a central metal-coated body 14 and several planar mirrors 15 which partially surround the body 14 but leave open at least a beam path for the ~~entering~~ entry and exiting of the radiation image from the mirror arrangement 13. By using such a mirror arrangement 13, ~~a~~

~~detection of~~ arbitrary radiation images can ~~take place~~ be detected independently of their spectral composition.

[0043] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.